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BULLETIN

OF THE

AMERICAN PHYSICAL SOCIETY

PROGRAM FOR THE

NEW YORK MEETING

FEBRUARY 22–23, 1929

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JOINT MEETING WITH THE OPTICAL SOCIETY OF AMERICA

AT COLUMBIA UNIVERSITY

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The American Physical Society

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BULLETIN

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AMERICAN PHYSICAL SOCIETY

NEW YORK MEETING, FEBRUARY 22-23, 1929

JOINT MEETING WITH THE OPTICAL SOCIETY OF AMERICA

The 156th regular meeting of the American Physical Society will be held in New York City on February 22–23, 1929, as a joint meeting with the Optical Society of America. All sessions will be held at Columbia University in the Physics Laboratories on 120th Street east of Broadway (entrance at 119th Street and Broadway).

Optical Society. On Friday morning and afternoon and Saturday morning there will be sessions of the Optical Society for the reading of papers in Room 428.

Physical Society. On Friday afternoon a session for the reading of papers will be held by the Physical Society in Room 401. On Saturday morning the Society will meet in two sections, one in Room 401 and one in Room 329. On Saturday afternoon there will be a single section in Room 401.

Joint Sessions. On Friday afternoon at 3:45 P.M. there will be a joint session of the Physical Society and of the Optical Society in Room 401 when PROFESSOR R. A. MILLIKAN of the California Institute of Technology will give an address on "*Cosmic Rays.*" The two Societies will meet again in joint session on Saturday monrning at 11:30 A.M. in Room 401 when PROFESSOR H. B. WILLIAMS of the College of Physicians and Surgeons, Columbia University, will speak on "*Some Physical Problems in the Field of Medicine.*"

Luncheon and Dinner. On Friday and Saturday luncheon and dinner may be had at the Men's Faculty Club (corner 117th Street and Morningside Drive). Further announcement will be made at the Friday sessions.

Headquarters Hotel for the Optical Society is the Bretton Hall at Broadway and 86th Street.

Abstracts. Titles and abstracts of papers to be presented are given in the following pages. These abstracts have not been corrected by the authors. After correction the abstracts of the Physical Society papers will be published in the Physical Review, and those of the Optical Society papers in the Journal of the Optical Society of America. Authors should send corrections to the editors of the respective journals.

W. L. SEVERINGHAUS, *Secretary, American Physical Society*
Columbia University, New York, N. Y.

February 9, 1929.

CALENDAR

All sessions will be held in the Physics Laboratories, Columbia University

Friday morning:	**10 o'clock;**	Room 428:	Optical Society Papers 1–7
Friday afternoon:	**2– 3:45;**	Room 428:	Optical Society Papers 8–10
	2– 3:45;	Room 401:	Physical Society Papers 1–8
Friday afternoon:	**3:45;**	Room 401:	Joint session of the two Societies. Invited address by PROFESSOR R. A. MILLIKAN.
Saturday morning:	**10:00–11:30;**	Room 428:	Optical Society Papers 11–12
	10:00–11:30;	Room 401:	Physical Society Papers 9–16
	10:00–11:30;	Room 329:	Physical Society Papers 17–23
Saturday morning:	**11:30 o'clock;**	Room 401:	Joint session of the two Societies. Invited address by PROFESSOR H. B. WILLIAMS.
Saturday afternoon:	**2 o'clock;**	Room 401:	Physical Society Papers 24–34

Other meetings of the Physical Society during the current season are as follows:

157. April 19–20, 1929. Washington.
158. June 19–22, 1929. Pacific Coast Section. Berkeley.
159. November 29–30, 1929. Chicago.
160. Pacific Coast Section. Time and place to be announced later.
161. Annual Meeting. Des Moines.

PROGRAM

FRIDAY MORNING AT 10 O'CLOCK

Room 428 Physics Laboratories, Columbia University.

Session of

THE OPTICAL SOCIETY OF AMERICA

OFFICERS

President, I. G. PRIEST, Bureau of Standards.
Vice-President, L. A. Jones, Eastman Kodak Co.
Secretary, C. C. BIDWELL, Lehigh University.
Treasurer, ADOLPH LOMB, Bausch & Lomb Optical Co.
Council: Consists of the above officers. P. D. Foote, F. K. Richtmyer, W. E. Forsythe, L. R. Ingersoll, P. E. Klopsteg, W. F. Meggers, A. H. Pfund.

ABSTRACTS OF PAPERS

1. Deane B. Judd — **Bureau of Standards**

THE REDUCTION OF DATA ON MIXTURE OF COLOR STIMULI

It has long been recognized that an infinite number of sets of distribution curves, or visual response functions (of which Weaver's set of "elementary excitation curves" recommended by the Colorimetry Committee[1] of this society is one) can represent a given body of data on mixture of color stimuli. The author has previously found[2] by the method of least squares the best luminosity coefficients applying to one of these sets of distribution curves and has shown that these curves weighted by these coefficients sum to a good approximation to the luminosity function of the standard "neutral." It has now been demonstrated that there exist coefficients for any of the infinite number of sets of distribution curves which will make them sum to identically the same approximation to the luminosity. Hence it is now possible to use any of these sets for computing from the spectral energy distribution the dominant wave length, colorimetric purity, and brightness of a color stimulus. (As a practical demonstration, this computation has been carried out for four stimuli by means of five different sets of distribution curves.)

This study has resulted in the discovery of a set of distribution curves (one of the above 5 sets) which gives the same numerical results as the set of O.S.A. "elementary excitation curves" but which is more convenient for computation. The convenience of this set of curves is due to the fact that one of them is the *luminosity function itself*. On this account the luminosity coefficients are $L_r=0$, $L_g=1$, and $L_b=0$. The Tuckerman symmetrical formula for colorimetric purity,[3]

$$p=\frac{3-\dfrac{1}{rL_r+gL_g+bL_b}}{3-\dfrac{1}{RL_r+GL_g+BL_b}}$$

becomes simply: $p=(3-1/g)/(3-1/G)$.

Bibliography:
1. Troyland, J.O.S.A. & R.S.I., *6*, p. 548; 1922.
2. Judd, J.O.S.A. & R.S.I., *10*, p. 635; 1925.
3. Judd, J.O.S.A. & R.S.I., *13*, p. 135; 1926.

The present paper will appear in full in Bureau of Standards Journal of Research — 20 min.

2. K. S. Gibson—Raymond Davis **Bureau of Standards**

METHODS FOR DETERMINING THE COLOR OF SUNLIGHT AND DAYLIGHT

The Davis-Gibson filters [1,2,3,4,5] afford means of accurately determining the color of sunlight and daylight.

1. *Source at 2848°K.* Filters have been designed for precisely duplicating the colors of: (1) Sun outside atmosphere (equivalent to overcast sky[5] or sun plus blue sky), (2) Washington noon sun, June 21, (3) Washington noon sun, Dec. 21, (4) Washington mean noon sun, $\frac{1}{m}$ all from Abbot's data of 1917. By adding Lovibond glasses of nominal grade from 0.0 to 1.0 and of known colorimetric values to the artificial sunlight or daylight, the color of the natural sunlight or daylight may be accurately determined. Data thus obtained in Sept. and Dec., 1928, will be illustrated.

2. *Source Varying from 2300°K. to 3000°K.* (Calibration of source may be made by means of Davis-Gibson filters.)[3] With filter (1), above, the color temperature will vary approximately from 4300°K to 7500°K, covering the range of daylight and noon sunlight. The color match with noon sunlight should be very close for all atmospheric conditions, the color of natural noon sunlight lying apparently between the black-body locus, which is relatively slightly purplish, and the colors given by filters (2), (3), and (4), above, which are relatively slightly greenish. Exact color match may be obtained by using Lovibond red glasses from 0.0 to 0.4.

3. *Source Varying from 2000°K to 3100°K.* The complete range of color temperature from 2000°K (or below) to 20,000°K may be covered by two filters:

(1) Source alone—2000°K (or below) to 3100°K.

(2) With first filter—approximately 2650°K to 5000°K.

(3) With second filter—approximately 4000°K to 20,000°K.

The deviations from black-body colors are very small, the colorimetric curves of the source and filter combinations crossing the black body curve at slight angles. These filters enable the complete range of color temperatures from the yellow of the setting sun to the blue of the sky to be measured. Lovibond red glasses may be used if exact match is desired.

The colorimetric characteristics of the filters will be illustrated. Measurements of intensity would also be possible, since the light transmissions of the filters are known.

Bibliography:
1. Davis & Gibson, J.O.S.A. & R.S.I., *14*, p. 135; Feb. 1927 (Abstract).
2. Phys. Rev. (2), *29*, p. 916; June, 1927 (Abstract).
3. J.O.S.A. & R.S.I., *16*, p 332; May, 1928 (Abstract).
4. Artificial Sunlight for Photographic Sensitometry, Trans. Soc. Motion Picture Engineers, *12*, pp. 225–236 1928.
5. A Filter for changing the Color Temperature of 2848°K to Average Daylight, B.S. Tech. News Bull. No 138, p. 143, Oct., and No. 139, p. 155, Nov. 1928.

15 min.

3. Arthur R. Riddle **The Hegeman Memorial Research Laboratory Metropolitan Life Insurance Company Sanatorium, Mount McGregor, New York.**

THE SHORT WAVE-LENGTH LIMIT IN SOLAR RADIATION, AS A FUNCTION OF TIME OF YEAR, AND TIME OF DAY

In light therapy, certain biological responses appear to come from stimuli of ultra-violet light of a very definite part of the spectrum. The region is found roughly to lie between 2900 and 3200 Angstroms. Since the solar spectrum does not cover all this, it seemed desirable to investigate the short wave-length limit, so far as might be permissible by spectrographic means. Spectrograms were made with a quartz spectrograph, the slit facing approximately south, towards a magnesium oxide reflecting surface, which received light from the north sky. Two sets of exposures were made, of all day duration, once a month, one for the brightest possible days, the other for the dullest—days usually quite overcast. Further sets of exposures were made for bright and dull days respectively, once each month, the spectrograph plate being changed every hour, from near sunrise to sunset. These results give approximately the short wave-length limit as a function of time of day. In the case of all day exposures, the short wave-length limit was—so far as light of this wave-length was able to produce a photo-

graphic image—as follows: for bright days, 303$\mu\mu$ in December, and 296 $\mu\mu$ in June; for dull days, 305$\mu\mu$ in December, and 296$\mu\mu$ in June. These figures give extreme cases for shortest and longest days respectively, when measurements were possible. Space does not permit the inclusion of any readings, showing variation over the day, from sunrise to sunset. These will appear in the full paper.

The present paper will appear in full in J.O.S.A. & R.S.I. 15 min.

4. W. T. Sproull and R. E. Martin **Lehigh University**

IONIZATION AND THERMAL E.M.F. IN SELENIUM VAPOR

Selenium vapor was produced in a pyrex tube which had previously been evacuated. A potential difference of 240 volts was impressed between two electrodes sealed in the tube, a sensitive galvanometer being in series with the circuit. The tube was illuminated with visible light. After eliminating spurious effects it was found that intensities up to 3500 foot-candles caused no ionization sufficient to alter the conductivity of the vapor as much as $\frac{1}{2}\%$. X-rays carefully screened from the electrodes produced a marked ionization (5 to 40%). Using a quartz tube, it was found that ultra violet light from a quartz mercury arc had no measurable effect. Only one faint mercury line (2537Å.) falls below the thermoelectric threshold for selenium (2670Å.). These results do not appear to support the theory that light action in selenium is a modified photoelectric effect.

During these experiments, one of the spurious effects discovered was a thermal e.m.f. in the selenium vapor. Keeping one electrode at 350°C, and varying the temperature of the other from 460° to 616°C, e.m.f.-temperature curves were obtained for the saturated vapor, the e.m.f. reaching to 0.58 volt. Thermal e.m.f. in the pyrex was of course taken into account. Measurements could not be obtained with accuracy unless the vapor was saturated, or nearly so.

15 min.

5. L. G. Hoxton **University of Virginia**

A DIRECT-READING ENGINE FOR SPECTRA

The instrument described here has been built as an attachment to one of the regular dividing engines made by the Societe Genevoise which happened to be the only one available. The purpose of the attachment is to enable one to obtain from the screw of the engine direct readings of either wave-lengths or frequency-numbers from photographs taken either with a prism or a grating, without having recourse to computation. The adaptation to any particular case is made by the adjustment of a small number of moving parts. A preliminary trial of the method has been successful.[1]

The principle employed is that of projection, which is one of the ways of realizing bilinear transformations of which the Hartmann computing formula is a case. This principle has been used before, optically[2] and graphically,[3] for example. The method here is mechanical.

Bibliography:
1. L. G. Hoxton, Physical Review, vol. 10, p. 90, 1917.
2. E. S. King, Harv. Coll. Obs, Annals, vol. 40, p. 205.
3. F. Henroteau, Monthly Notices, Roy. Astr. Soc., vol. 77, p. 77.

15 min.

6. R. V. Baud **Westinghouse Elec. & Mfg. Company**

FURTHER DEVELOPMENT IN PHOTO ELASTICITY

It has been customary in the past to machine the models used in photo-elastic work either of glass or celluloid and to use a compensator for measuring the difference $p-q$ between the principal stresses p and q, point by point.

In this paper a new method is outlined, consisting of using models made of a material of a large index of forced double refraction and of making photographs or drawings of the isochromatics of the loaded model and of a comparison strip in bending. By matching the colors of the model with those of the strip in bending a complete quantitative record of the shear-stress distribution throughout the model is obtained.

An example of the application of this new procedure is given for the case of a plate with a hole subjected to tension along one axis. Since the theory of elasticity offers an accurate solution for this particular case it can be used as a means of confirmation. The paper shows a very good agreement between analysis and experiment.

10 min.

7. R. V. Baud — **Westinghouse Elect. & Mfg. Company**

EXPERIMENTAL METHODS OF STUDYING STRESS DISTRIBUTIONS

The photo-elastic, strain measurement, analogy and Lueder's line methods of studying stress distributions are discussed in this paper. It is concluded that these methods make extensive use of optics and it is suggested that this interesting field be given some attention by the optical industry.

The present paper will appear in full in J.O.S.A. & R.S.I. 10 min.

FRIDAY AFTERNOON AT 2:00 O'CLOCK

Session of the Optical Society

Room 428

8. Selig Hecht and Ernst Wolf (By invitation) — **Columbia University**

THE VISUAL ACUITY OF THE BEE

The characteristic response which bees make to a movement in their visual field furnishes a method for measuring their visual acuity. In this way it is found that the maximum visual acuity of the bee is lower than the lowest human visual acuity. Under similar maximal conditions human visual resolution is about 100 times that of the bee. The bee's eye is a mosaic of hexagonal pyramids of differing apical angle, which determines the separation of adjacent ommatidia. The minimum visual angle which the bee can discriminate as measured experimentally is identical with the minimum angular separation of adjacent ommatidia as found structurally. If this region of minimum ommatidial separation is painted out, the maximal visual acuity then corresponds to the angular separation of the remaining ommatidia.

The visual acuity of the bee varies with the illumination in much the same way that it does for the human eye. It is low at low illuminations; as the intensity of illumination increases it increases; and finally at high intensities it becomes constant. The resolving power of a structure like the bee's eye depends on the distance which separates the discrete receiving elements. The data then mean that at low illuminations the distance between receiving elements is large and that this distance decreases as the illumination increases. Since such a moving system cannot be true anatomically it must be interpreted functionally. It is therefore proposed that the threshold of the various ommatidia are not the same but that they vary as any other characteristic of a population. The visual acuity will then depend on the distance apart of those elements whose thresholds are such that they are functional at the particular illumination under investigation. Taking due consideration of the angular separation of ommatidia it is possible to derive a distribution curve for the thresholds of the ommatidia which resembles the usual probability curves, and which describes the data with complete fidelity.

The present paper will appear in full in Journal of General Physiology 35 min.

9. Edward Adams Richardson (Introduced by P. L. Bayley) — **Bethlehem Pa.**

RELATIVITY VERSUS THEORIES OF LIGHT

The hypothesis that the velocity of light should be measured relative to the source, and the closely related hypotheses that the velocity of propagation of electrical and gravitational fields should be measured relative to the electrons and matter respectively, are considered.

This paper points out the importance of psychological considerations in the development of scientific points of view with special reference to the rise of Einstein's theory of relativity. It then proceeds to point out the application of the above hypothesis to Michelson and Mor-

ley's repetition of Fizeau's experiments on "aether drag" in moving refracting mediums, their later experiments on the velocity of the earth relative to the "aether," and Airy and Hoek's experiments, on the angle of aberration, using telescopes filled with water and with air, and shows that such a hypothesis satisfactorily correlates them. Next the time required for a light ray to proceed from a source, moving with constant velocity, to the observer is determined both for the aether wave theory and the suggested hypothesis. The ratio of times for the special case of nearest approach of the moving body is that required by the Lorentz transformation.

From this point on, the paper is suggestive in character, pointing out the advantages of such a hypothesis from the standpoint of suggesting new lines of investigation. The theories of Einstein are regarded as mathematical processes for correcting the errors of an aether wave theory according to an arbitrary scheme which approximates more or less closely to the true mechanism, but have no physical, metaphysical, or philosophical importance from the standpoint of making time and space a four dimensional continuum of twisted space.

The unexpected result of Einstein's calculations regarding the precession of the perihelion of Mercury is interpreted as strongly supporting the view that gravitational potentials are propagated with the velocity of light relative to the gravitating body, hence must be closely related to electricity and light.

Bibliography:
Earth's Velocity Phil. Mag., vol. xxiv, p. 449, 1887.
Fizeau's Exper. Amer. Jour. of Sc. (3), vol xxxi, p. 377, 1886.

15 min.

10. Dr. Ludwig Silberstein — **Kodak Research Laboratories**

ILLUMINATED SPACE-TIME: OPTICAL EFFECTS OF ISOTROPIC RADIATION SPREAD OVER ELLIPTIC SPACE

Einstein's gravitational field equations are integrated for the case in which the space is filled with isotropic radiation. This case is, natural, of interest, since our space is actually traversed in all directions by radiation emitted from all stars, nebulae, etc. The complete solution of the problem is given and discussed for its implications, especially those relating to the Doppler effect.

The present paper will appear in full in Phil. Mag. 20 min.

FRIDAY AFTERNOON AT 2 O'CLOCK

Session of the Physical Society

Room 401

1. The positive column of the mercury arc. T. J. KILLIAN, Princeton University.—The mechanism of the uniform positive column of a mercury arc has been studied by means of the Langmuir probe electrode method. Measurements of the random electron and positive ion currents, electron temperatures and space potentials were made both along a diameter and along the axis of a long cylindrical tube. The mean free path of electrons in mercury vapor as given by the Langevin mobility equation ($\mu = 0.815 e\lambda/mv$) was found to be somewhat smaller than that previously obtained by other methods. The ratio of the densities of electrons at any two points along a diameter is related to the difference between the potentials at the points by the Boltzmann equation, $n/n' = e^{ev/kT}$ where T is the temperature of the electrons. From 15 to 50 percent of the energy input per unit length, depending upon the electron temperature, is delivered to the walls by the recombination of positive ions and electrons.

2. Angular distribution of secondary electrons in helium. G. P. HARNWELL, Princeton University.—A beam of electrons was projected through a region of high gas pressure and the electrons emerging at various angles with the original beam were analysed. Three types of electrons were found: those which had been scattered with no loss of energy, those which had lost the exciting or ionizing energy, and also a group of very slow electrons with energies vary-

ing from 0 to 10 or 15 volts. One of these last two groups may represent the primary and the other the secondary electrons. The angular variations of these groups at large angles were very similar. At small angles, however, there were many more of the electrons with smaller energy. A possible interpretation is that this group represents the primary electrons and they predominate over the secondary electrons at small angles because they have retained a component of momentum in the forward direction. However, this evidence is not conclusive, and the behavior is not identical in other gases. But if this is the correct explanation it means that the primary electron gives up nearly all its energy to the helium atom and the excess over the ionization energy is carried away by the secondary electron.

3. The electrical breakdown of liquids. J. W. BEAMS, University of Virginia.—The time lag of the spark discharge through liquids as well as the spectrum emitted at the beginning of the spark have been studied by a method previously described (Journal Franklin Inst. 206, 809, 1928). The time lag decreases with increasing field strength. In some dielectrics such as kerosene oil, nujol or carbontetrachloride an impressed field of over 3×10^6 volts per cm is required to reduce the time lag to values less than 1.5×10^{-8} sec. also the fluctuations in the time lag are less than those observed for air and decrease with increasing field strength. When once a spark has occurred through a dielectric the time lag is decreased. The spectra first emitted in a discharge through a pure liquid appear practically continuous throughout the visible region in all cases investigated. In the spark between mg electrodes 2mm apart in running water the spectrum first appearing is continuous followed by the mg spark line at 4481A. and the mg arc triplet 5184, 72, 67A which appear as emission lines. The arc triplet however appears as very faint absorption lines when the total light from the spark is observed.

4. Conditions for initiation of electrodeless discharges in gases. N. T. GORDON AND S DUSHMAN, General Electric Co.—Experiments have been carried out to determine the minimum current through a copper coil which will suffice to start a glow in a bulb placed inside the coil when the latter is supplied with high frequency current from a vacuum tube oscillator. Neon, helium and oxygen have been investigated at pressures ranging from 0.1 mm to 40 mm and at the frequencies 8.26×10^5 (363 meters), 16.04×10^5 (187 meters) and 31.58×10^5 (95 meters). For each frequency there exists a critical pressure at which the current through the coil required to initiate the glow is a mimimum. The following table gives the values observed for a bulb 7.6 cm diameter placed in a copper coil 12.7 cm in diameter and consisting of 23 turns.

Minimum Current and Pressure

Gas	363 meters	187 meters	95 meters
Neon	1.1 amp. (7.0 mm)	0.49 amp. (3.0 mm)	0.44 amp. (3 mm)
Helium	1.3 " (3.0 ")	0.49 " (1.5 ")	
Oxygen	4.8 " (0.3 ")	1.7 " (4.0 ")	0.65 " (0.2 mm)

The effect of varying the bulb diameter was investigated; also the influence of electrostatic fields (as distinguished from those of electromagnetic nature). The phenomena exhibit a parallellism with positive column discharges which would necessitate taking into account charges on the walls.

5. Ion paths in constant electric and magnetic fields. LEIGH PAGE, Yale University.—J. J. Thompson has shown that an ion with zero initial velocity describes a common cycloid in crossed fields and drifts at right angles to the plane of the fields with a velocity of cE/H. Gunn has shown that the mean drift velocity is independent of the initial velocity and Maris and Hulburt have found a similar drift in a gravitational field, but these authors have not investigated the ion paths in detail. By a simple transformation to a moving set of axes it is shown that the effect of a constant electrical or gravitational force **F** on ions passing through a constant magnetic field **H** is (1) to change the radius of the circular or helical path of an ion about the lines of magnetic force from $(mc)v_0/(eH)$ to $(mc/eH)(v_0^2-2uv_0+u^2)^{1/2}$ where v_0 represents the component of the initial velocity perpendicular to **H** and u is defined

below, and (2) to cause the circular or helical path to advance with the constant velocity $u=(cFH)/(eH)^2$ in a direction at right angles to both **F** and **H**. The paths are therefore curtate, common or prolate cycloids described by the same rolling circle.

6. Dependence of electron emission from metals upon field strengths and temperature. R. A. MILLIKAN AND C. C. LAURITSEN, California Institute of Technology.—This paper contains a full presentation of the reasons for believing, contrary to results recently obtained elsewhere, that field currents are only independent of temperature up to about 1100°K, and that at that temperature the energy of thermal agitation begins to assist the fields in causing the escape of electrons from metals. The precise form of function describing this dependence is not accurately determinable experimentally, but the form originally suggested by us fits the facts of observation thus far known satisfactorily, not better, however, than does the theoretical form suggested by Houston.

7. The caesium-magnesium photo-cell. V. ZWORYKIN AND E. D. WILSON, Westinghouse Electric and Manufacturing Co.—The values of the work functions of the alkali metals and their color-sensitivity curves indicate definitely that caesium is the most favorable material for use in photo-cells. The practical difficulties of handling caesium metal have been overcome in the caesium-magnesium cell, in which a freshly evaporated coating of magnesium not only binds an invisible layer of caesium to the walls of the cell, but also provides an electrical connection with the cathode terminal. Average color-sensitivity curves are given for more than twenty cells. They show that the maximum sensitivity lies at about 4850A, as compared with 4400A for pure potassium, 5390A for pure caesium, and 5560A for the human eye. The photoelectric properties of the cell are detailed by means of response-voltage curves, response-illumination curves and illumination limit curves. The maximum response for vacuum type cells is about 2 microamperes per lumen, and for gas-filled cells about 25 microamperes per lumen under normal operating conditions. Several commercial applications are described. Further development work is now in progress.

8. Non-linearity of photoelectric response near long wave-length limit. W. B. NOTTINGHAM, Bartol Research Foundation.—The fact that the long wave-length limit for thin alkali metal films coincides with the first line of the principal series was reported by Ives and Oplin (Abstract 19, New York Meeting, Dec. 27, 1928). This observation naturally suggests that the photoelectric current produced by illumination of a wave-length very near this long limit might come about as a result of cumulative action of two light quanta, one producing a state of excitation and the second producing ionization. A test of this theory has been carried out with a cell having a cylindrical nickel anode and a concentric platinum cathode on which some potassium was distilled and later partly evaporated off. The above mentioned observation of Ives and Oplin was verified and the predicted non-linearity of the photoelectric current was found to exist. The current increased almost exactly nine fold when the light intensity was increased by a factor of three, thus showing that under this very special condition the photoelectric effect is the result of the cumulative action of two light quanta for each electron.

FRIDAY AFTERNOON AT 3:45 O'CLOCK

Joint Session of the Optical Society and the Physical Society

Room 401

An invited address by

PROFESSOR R. A. MILLIKAN — California Institute of Technology

"Cosmic Rays"

SATURDAY MORNING AT 10 O'CLOCK

Session of the Physical Society

Room 401

Paper No. 9 will be read by title.

9. Determination of frequency and decrement by means of plate current variations of thermionic oscillator tubes. J. TYKOCINSKI-TYKOCINER AND R. W. ARMSTRONG, University of Illinois.—The intensity of the plate current feeding a thermionic oscillator varies with the frequency ω of a coupled circuit. If the condenser setting of the latter is varied and ω plotted against ΔI_p, resonance curves are obtained representing $\Delta I_p = f(\omega)$. These curves were investigated within a range of 150 to 100000 kc. The influence of filament current I_f, plate potential E_p, coupling k and damping decrement δ was studied. The existence of critical values I_f' and E_p' was discovered for which $\Delta I_p = 0$. Above these values $I_p = f(\omega)$ is represented by peaked resonance curves, below these values the curves are inverted showing a depression. The character and the maximum values of the $\pm\Delta I_p$ curves depend also on the coupling and damping coefficients of the circuits. With the exception of a narrow zone near the critical points, the ΔI_p curves were found to correspond to Bjerknes resonance curves obtained with a thermogalvanometer inserted in the coupled circuit. By compensating the steady part of I_p a sensitive method was developed for measuring the frequency and logarithmic decrement of oscillating circuits, parallel wire systems and antennae. No thermocouple or any other device need be inserted in the measured circuit. The constants of the latter remain therefore unaffected by measurements.

10. Measurement of amplitude ratio and phase difference at the ears due to a source of pure tune. F. A. FIRESTONE AND D. L. RICH, University of Michigan.—A life sized, man shaped dummy with a wax head was fitted with Baldwin receivers in its ears, having their diaphragms where the ear drum would normally be. The source of sound was a loud speaker unit connected to a pipe which had its opening flush with the roof of the building. The dummy was mounted horizontally above the source and was so arranged that it could be turned about its axis and also adjusted to different distances from the source. The voltages generated by the microphones in the ears were measured in magnitude and phase by a null method involving an alternating current potentiometer driven from the same oscillator that supplied the source. Harmonics were eliminated. Readings were taken with the source at varying azimuths around the head; at 256, 1024, and 1944 cycles per second; and at distances of 20, 50, 100, and 400 cm from the head. The measurements for the two lower frequencies agree within 15 percent and 15° with the values published by Hartley and Fry computed on the assumption that the head is a rigid sphere in free space. The measured and computed values at 1944 cycles do not agree so well.

11. Measurement of sound absorption coeffcients. PAUL E. SABINE, Riverbank Laboratories.—The time t_1 required for the reverberant sound from a source of acoustic power E_1 (ergs/sec) to decrease to the threshold i(ergs/cu. m) in a room whose volume is V cu. m and absorbing power is a square meters of complete absorption is given by the equation (1) $t_1 = (9.2V/av) \cdot \log_{10}(4E_1/av_1)$. With a source whose acoustic output can be varied in known ratios a is found by the equation (2), $a = 9.2V/v) \log_{10}(E_1/E_2)/(t_1 - t_2)$. Using a telephonic loud speaker a linear relation between the logarithm of the current input and the reverberation was found, but the slope of the line, assuming E proportional to the square of the current was greater than a similar straight line using a number of simultaneously speaking organ pipes as the variable source. Measurements based on equation 2, using a loud speaker source gave higher values of the absorption coefficients than those based on equation (1) using the same source. Intense tones gave higher coefficients than faint tones of same pitch and

quality, as did also complex tones compared to pure tones of same pitch and intensity. Experiments indicate that the absorption coefficient of a porous material is a function of pitch, quality, and intensity so that reverberation measurements should be made under specified conditions as to these three factors.

12. Repeated reflection of atoms from crystals. A. ELLETT AND H. A. ZAHL, State University of Iowa.—The beam of cadmium atoms specularly reflected from a halite crystal impinging upon a second crystal is specularly reflected only when incident upon this crystal at the same or nearly the same angle at which reflection from the first crystal took place. When both angles of incidence are the same the entire beam incident upon the second crystal appears to be specularly reflected. A change of ten degrees in the angle of incidence upon the second crystal causes a marked loss of intensity in the specularly reflected beam, and it disappears when the angles differ by 25° to 30°. Under the latter conditions the beam specularly reflected from the first crystal is scattered at random by the second giving rise to a typical cosine distribution. These results show that the probability of specular reflection depends in a critical manner upon the velocity of the incident atoms. The probability of reflection of atoms whose velocity differs from the critical velocity by ± 15 meters per second is evidently less than half the probability at the critical velocity, and we may conclude that the "resolving power" is between the limits 0.01 and 0.05.

13. Intensities of general x-radiation proceeding from an atom in different directions. WILLIAM DUANE AND J. C. HUDSON, Harvard University.—Experiments have been described (William Duane, Proc. Nat. Acad. Sci., 14, 450, (1928)) which showed that, when a homogeneous stream of electrons impinges on mercury vapor atoms, a considerable amount of radiation proceeds forward in the direction of motion of the electron stream, as well as right angles to that direction. The radiation projected forward was several times as intense as that projected at right angles. As mentioned before, this might have been due to the fact that the former came from a thicker layer of mercury vapor than did the latter. The object of the experiments described in this paper has been to investigate the intensities of the radiation projected (a) at 45° from the direction of motion of the electrons and (b) exactly opposite to this at 135°. These two beams must have come from the same thickness of mercury vapor. The intensities of the beams were measured both by the ionization method and by photometering the photographs shown at this meeting. It appeared that the radiation projected forward at an angle of 45° from the direction of motion of electrons was about twice as intense as that projected backward at an angle of 135° from the same direction.

14. Determination of the orientation of metallic single crystal specimens by high voltage x-rays. THOMAS A. WILSON, General Electric Company, and Dept. of Chemistry, Union College.—The specimens involved in this work were single crystals of silicon steel which had been grown in strip form. For various reasons, the orientations of these specimens had to be determined by the Laue method. The usual 30 kv radiation from a Mo target was unsuitable for this work because of its low penetration. The source of radiation used was a Coolidge deep-therapy tube, with tungsten target, which was operated at 270 kv. peak. The crystal under examination was mounted in a goniometer so that patterns could be obtained with the crystal in various positions with respect to the x-ray beam. When a photograph showing some easily recognizable symmetry was obtained (2-fold symmetry was sufficient) the orientation of the crystal was derived by use of the gnomonic projection. The method is adapted for quantity determinations because of its speed.

15. The relation between the continuous and line spectra of x-rays from thin targets. D. L. WEBSTER AND W. W. HANSEN, Stanford University.—The process of K-electron ionization by cathode-ray impact has a continuous-spectrum counterpart in the emission of a quantum of any frequency above the K limit. The ratio Q, of the probability of the former process to that of the latter, appears for thick targets of silver to be constant within reasonable

limits of error. (Proc. Nat. Acad. Sci., June, 1928). The inference that it is likewise constant for thin targets is subject to much wider limits of error. However, estimating the form and intensity of the thin-target continuous spectrum of silver by slight modification of Kulenkampff's data for aluminum (Ann. d. Physik., Dec. 1928), the probability of the above continuous-spectrum process can be calculated. It is found approximately proportional to measured Kα-line intensities between 25 and 85 kv (Proc. Nat. Acad. Sci., Sept. 1928). This furnishes additional evidence that Q is constant even for thin targets. A formula for either of these probabilities, suggested by simplification of the above calculations, is constant $\times U^{-n} \log U$, where $U = V/V_K$. With $n = 0.65$, obtained from Kulenkampff's data, this formula gives the line intensities within about 5 or 10 percent; with $n = 0.75$ or 0.80, it holds within 2 percent.

16. A high potential electrostatic voltmeter. S. W. BARNES AND F. K. RICHTMYER, Cornell University.—This electrostatic voltmeter departs from the common two sphere and dumb-bell type in having but two spheres between which the electrostatic forces act. The feature of the instrument is the arrangment for getting rotational movement from the vertical displacement of the upper sphere. This sphere is supported by a coiled spring and two fibers which are caused to wind in opposite directions around a small cylinder on the sphere by the twist of the spring. The fall and rotation of the suspended sphere is proportional to the square of the difference of potential of the spheres. The advantages of this type are those of relative small size and flexibility. The range of the instrument may be changed by varying the distance between the spheres. One designed to read to two hundred kilovolts has detected one hundred and ten volts when the scale was reduced by raising the lower ball. Ageing the coiled spring prevents zero drift.

SATURDAY MORNING AT 10 O'CLOCK

Session of the Physical Society

Room 329

17. Compressibility of crystals and atomic fields. N. RASHEVSKY.—Westinghouse Electric and Mfg. Co.—A system of submicroscopic cracks is usually made responsible for the great difference between the actually found tensile strength of crystals and the theoretically computed one. It is pointed out that this system of cracks should have also an effect on the compressibility. It is shown that the compressibility of an ideal crystal may be considerably smaller than that of a real crystal. Since the compressibilities of crystals are used to calculate the exponent of the force of repulsion between ions (resp. atoms), the effect of the cracks will be to give us too low values for this exponent. Possible ways of investigating this influence are suggested.

18. Atomic order in ferromagnetism. L. W. MCKEEHAN, Yale University and O. E. BUCKLEY, Bell Telephone Laboratories.—The fields surrounding a paramagnetic atom in a ferromagnetic substance cannot possess spherical symmetry, even in a cubic crystal. The magnetic field has at least one distinguishable axis determined by the resultant magnetic moment of the atom. The mechanical field, responsible for cohesion and rigidity, must also have distinguishable lines or planes, and these must be definitely oriented with respect to the magnetic axis (but differently in atoms of different elements) to account for magnetostriction. The degree to which such distinguishable parts of different atoms in a specimen have a common orientation may conveniently be called its degree of magnetic order or mechanical order. In alloys the two sorts of atomic order may be inconsistent. The effects of mechanical, chemical and thermal processes upon mechanical order are predictable and the profound changes in magnetic behavior under weak and moderate magnetic forces which can thus be produced are thereby more easily explained. It becomes possible to write specifications for a ferromagnetic material with desired combinations of properties. Measurements of electrical re-

sistance disclose the existence of atomic order in cases where magnetic and mechanical measurements are incompetent. Mechanical order may be of importance in some of the diamagnetic metals.

19. The Barkhausen effect in iron nickel and permalloy. RICHARD M. BOZORTH, Bell Telephone Laboratories, Inc.—Experiments show that the changes in magnetization which take place suddenly in large groups of atoms (Barkhausen effect) account for the whole change in magnetization over a considerable part of the hysteresis loop. Substantially all of the groups which act as magnetic units on the steeper parts of the loop are large enough to be detected with a search coil and amplifier. The apparent large differences in the effect in various materials, and in the same material in different forms, are due to the different rates of decay of eddy-currents in them. The average size of the group is of the order of 10^{-7} cm³ for the steeper parts of the hysteresis loops for annealed iron, nickel and permalloy, for hard worked iron, and for a single crystal of iron.

20. Capillary phenomena in non-circular capillaries. W. O. SMITH AND PAUL D. FOOTE, Mellon Institute of Industrial Research.—The height of rise of a liquid of density ρ and surface tension σ in a cylindrical capillary of any section is shown to be given by $h=(\sigma P \cos\theta)/gA$ where P is the perimeter of the tube, A its area of section, θ the angle of contact and g the acceleration of gravity. Application is made to square and elliptical tubes. Data are given for the rise of carbon tetrachloride and water in elliptical capillaries of various eccentricities. The above formula gives much better agreement than the one commonly used viz. that for a circular tube with radius equal to the geometric or arithmetic mean of the semi axes.

The vapor pressure over the meniscus is shown to be given by $p-p_0=(d\sigma P \cos\theta)/(\rho A)$. A more accurate formula is $\log p_0/p=(d_0\sigma P \cos\theta)/(\rho-d)(p_0 A)$; p_0 is the vapor pressure over the free liquid, p that over the meniscus, and d_0 the vapor density over the free liquid.

21. A new system of dynamics. ARTHUR E. RUARK, Mellon Institute, Gulf Oil Companies and University of Pittsburgh.—The differential character of the equations of motion implies that a dynamical system is governed by laws operating with a precision beyond the limits of detection by experiment. This feature is undesirable, and it seems logical to introduce the general principle that *all physical phenomena can be described without the use of infinitesimals or infinites.* Like many other common sense physical postulates, this leads to surprising consequences. It requires us to use calculus of finite differences in formulating basic physical laws. In dynamics, the use of this calculus yields terms corresponding to the fact that *the configuration is known only when we observe it and must be arbitrary at intermediate times.* Example: If a "uniformly moving particle" is observed every second we find experimentally that $\Delta^2 x/\Delta t^2=0$, which replaces Newton's law. Integrating, $x=Ft+G$, where $F=\Sigma F_n \sin 2\pi nt$ and G is a similar arbitrary *Fourier* series. Relativistic dynamics may be attacked through a finite variation principle, replacing the geodesic law, and is not yet satisfactorily worked out. For small systems, finite dynamics should be connected with the indetermination principles of Heisenberg (Zeits. Phys. **43**, 172) and of the author (Proc. Nat. Acad. **14**, 322). The philosophic advantages of this formulation are obvious.

22. Application of the Fermi-Dirac statistics to specific heats of solids. A. T. WATERMAN, Yale University.—It is assumed that a solid consists of a system of harmonic atomic oscillators, each with three degrees of freedom. On applying the Fermi-Dirac statistics to such an assembly the mean energy per oscillator is found to be $U=3kTG(A)/F(A)$, where $F(A)$ and $G(A)$ are the Fermi integrals. For the classical state of the assembly $U=3kT$, and the specific heat $C_v=3NK$, in agreement with the Dulong-Petit law. In the limiting case of extreme degeneracy C_v is proportional to the absolute temperature, vanishing at 0°K. The computed form of the specific heat curve over the intermediate range is roughly that found experimentally, but shows no point of inflection. According to this view-point the departure of the atomic heat for a given element from the Dulong-Petit value is due to increasing degeneracy in its system of oscillators.

On arranging the elements in order of increasing degeneracy at a given temperature this order is precisely that of the observed departure from the Dulong-Petit law. The temperatures however at which marked departure from the Dulong-Petit specific heat value occurs on this hypothesis are in every case of the wrong order of magnitude, being too low.

23. Essay toward a new logic in physics. JOHN Q. STEWART, Princeton University.—Types of physical atomicity are molecules, electrons, and photons. Corresponding field theories are: heat and hydrodynamics, electromagnetic theory, and wave theory of light. In the microscopic theories three symmetrical equations express the energy of the "degree of freedom" as $\frac{1}{2}kT$, eV, $h\nu$, respectively. Thus temperature, electrostatic potential, and frequency are in a sense the same sort of thing. Likewise Boltzmann's constant, k, "Millikan's constant," e, and Planck's constant, h, are symmetrically related. As k has dimensions of entropy, the suggestion is that entropy occurs in three modes, being analogous with charge and action. On this view the distinction should carefully be maintained between mechanical work, and energy increments which are associated with variations in intropy, charge, or action. The argument that entropy is explained by probability can be inverted, probability being defined by reference to a prior intuition which corresponds to the second law of thermodynamics. Although reasoning by broad analogy is received with caution, it is certain that thermodynamics offers an advanced base for exploring toward a synthesis of physical laws. For such an attempt guidance is found in Leibniz rather than in Newton.

SATURDAY MORNING AT 10 O'CLOCK

Session of the Optical Society

Room 428

11. Herbert E. Ives — **Bell Telephone Laboratories**

MOTION PICTURES IN RELIEF

This paper describes an extension of the idea of the parallax panoramagram recently described before the Society.* A special projection screen is used consisting of a translucent sheet in front of which and behind which are placed, with a small separation, opaque line gratings having opaque spaces much wider than the transparent. Upon this screen are projected simultaneously, from the rear, a large number of motion pictures from a wide range of directions. Each motion picture is thus broken up into narrow strips upon the screen and, according to the position of the observer on the viewing side, different pictures are seen. The motion picture films for projection are taken in a correspondingly large number of motion picture cameras, all directed from various positions at the same object. The number of different points of view and consequently the number of motion picture cameras and projectors should be such that the cameras or projectors are practically in juxtaposition throughout the whole angle of view covered. Means are suggested by which the number of points of view may be multiplied by running the apparatus at high speed and securing several points of view for each ordinary frame projection period. The proposed method is unique among suggestions for projection of motion pictures in relief in that it calls for no viewing apparatus at the eyes of the observers. On the other hand, the apparatus for taking and projecting the pictures is cumbersome and costly.

* Journal of the Optical Society, December, 1928.

The present paper will appear in full in J.O.S.A. & R.S.I. — 15 min.

12. Harry Helson (By Invitation) — **Bryn Mawr College**

THE EFFECTS OF DIRECT STIMULATION OF THE BLIND SPOT

Upon directly stimulating the optic disc by means of a light source exposed within the projection of the blind spot and of such size that the diameter of the image on the nerve head may be as small as 1/135 the diameter of the optic disc, all observers report a more or less

diffuse light with a brighter core usually corresponding to the color of the stimulus. Exceptions to this rule will be discussed. If the observer is quick enough he can catch the form of the stimulus in the first moment of exposure after which details disappear. Adaptation occurs so rapidly that weak stimuli fade out soon after being seen. Two colors exposed either as rectangles side by side or as concentric rings within the blind spot can be seen simultaneously. When the region surrounding the blind spot is stimulated so that most intense stimulation occurs at the boundaries of the blind spot, thereby fulfilling the conditions of the irradiation, gradient, and dispersion theories of vision in the blind spot, no bright central core is reported, often nothing is seen in the region of the optic disc. If stimuli fall in the center of the blind spot and around its edges, with proper adjustment of the intensity, observers report that between what is seen in the blind spot and immediately outside there is a dark interval, showing irradiation or diffusion does not reach in this case beyond the boundaries of the disc to adjoining sensitive retinal elements. Numerous experiments designed to test the irradiation, dispersion and diffusion theories will be reported. It is generally agreed that contrast effects, after-images and the like show that there is vision *in* the blind spot at times, but our experiments seem to show that there is vision *with* the optic disc. In the light of our experiments and until some more refined technique has demonstrated to the contrary the only possible interpretation we can give at present to our results is that they are due to direct stimulation of the optic nerve fibres with resulting sensations of light. We may say that when the optic nerve head is stimulated to a greater degree than the rest of the fundus light will be seen and that the "blind" spot under such conditions is not blind.

The present paper will appear in full in American Journal of Psychology, vol. 41, July 1929. 40 min.

SATURDAY MORNING AT 11:30 O'CLOCK

Joint Session of the Optical Society and the Physical Society

Room 401

An invited address by

PROFESSOR H. B. WILLIAMS — College of Physicians and Surgeons, Columbia University

"Some Physical Problems in the Field of Medicine."

SATURDAY AFTERNOON AT 2 O'CLOCK

Session of the Physical Society

Room 401

Papers No. 24, 25 and 26 will be read by title.

24. Further combinations in the spark spectrum of nickel. R. J. LANG, University of Alberta.—The lowest term of the first spark spectrum of nickel is a doublet D term from the configuration d^9. The value of these terms relative to $(d^8s)^4F'$ was reported in a previous paper to be -6884 and -8391 cm^{-1}. These term values were derived from combinations between this lowest D term and the following terms of the d^8p configuration: $^4D'$, F, G'; $^2D'$, F, G'. The remaining twelve terms of the d^8p configuration namely: $^4S'$, P, D'; $^2S'$, P, D'; ^2P, D', F; ^2F, G', H; have now been found to combine with the lowest ^2D term resulting in twenty-six lines lying between 1537 and 1250A.

25. The spectrum of the aurora borealis. JOSEPH KAPLAN, University of California at Los Angeles.—The difference $^1D_2-{}^3P$ in the O_I spectrum can be calculated by assuming that the ratio of the differences $^1D_2-{}^3P$ and $^1S_0-{}^1D_2$ in O_I is equal to the same ration in O_{III}.

The value obtained is 1.96 volts. Bowen, by entirely different considerations obtained a value equal to 2.05 volts. The 1.96 value for the difference $^1D_2 - {}^3P$ and the 2.23 value for the difference $^1S_0 - {}^1D_2$ have been used by the author to explain the excitation of the α bands 6470, 6323 and 5925 which are the only α bands that have been observed in the aurora. These bands are excited by collisions between metastable oxygen atoms in the $^1S_0$ and $^1D_2$ levels and metastable nitrogen molecules in the A_4 level. The presence of N_2 in this level can be explained by considerations similar to those that enter into the explanation of the nitrogen afterglow. This method indicates also that there are very few metastable nitrogen atoms in the aurora. The level B_{10} (the initial level of 6323) can also be excited by collisions between N_2 in the A_0 state and N_2^+ in the upper level of the two most intense bands in the aurora. The energy available agrees exactly with that necessary for the transition $A_0 \rightarrow B_{10}$.

26. Active nitrogen. JOSEPH KAPLAN, University of California at Los Angeles.—Recently Cario and the author have called attention to evidence for the existence of metastable atoms and molecules in the nitrogen afterglow. The new value of the heat of dissociation of nitrogen to which attention has been called independently by Birge, Mulliken, Herzberg and the author, makes two reactions in the afterglow especially interesting. The heat of dissociation of nitrogen proposed by Hirzberg and the author is equal to 9.1 volts. Therefore, by recombination between a normal nitrogen atom and one in the metastable ^2D state, it is possible to excite the B_{11} level of the molecule, since the energy available in this process is 11.47 volts and the energy necessary for the excitation of the B_{11} level is 11.46 volts. Instead of a recombination between a normal atom and a metastable one we can consider the recombination between two normal atoms to form a metastable molecule possessing 9.1 volts and then the subsequent excitation of this by an atom in the ^2D state, once more giving a molecule in the B_{11} level. In this way we can account for the fact that the bands arising on the B_{11} level are the most intense ones in the afterglow.

27. The continuous spectrum of hydrogen. JOSEPH KAPLAN, University of California at Los Angeles.—The recent experiments of Jones and Whiddington have shown that the excitation potential of hydrogen at 12.6 volts is the most probable one at low voltages. They have failed to observe the excitation of the triplet levels. Because of this the explanation of the continuous spectrum of the hydrogen molecule proposed by Winans and Stueckelberg is modified and most of the spectrum is now said to arise in transitions between the *C* level and the new 1^3S level of Heitler and London. This explanation is in good agreement with the failure of Oldenberg to observe the continuous spectrum in argon-hydrogen mixtures and with the disappearance below 13.5 volts of the blue glow in the experiments of Horton and Davies. It also makes possible the explanation of the new observations of Jones and Whiddington of energy losses in electrons, corresponding to the entire range from about 8 or 9 volts to zero. These are said to correspond to transitions from the 1^3S level to the *C* level.

28. Dependence of ultraviolet reflection of Ag on plastic deformation. HENRY MARGENAU, Yale University.—The change in electrical conductivity of metals with mechanical strain suggests the possibility of a dependence of optical reflecting power on plastic deformation. To study this matter, and to obtain additional evidence with regard to the nature of cold working, the behavior of the minimum of reflecting power of silver in the near ultraviolet (at 3160Å according to Rubens and Hagen) was examined for silver surfaces of varying degrees of strain, produced by vigorous and moderate polishing, etching, and electroplating. Reflection curves were obtained by measuring directly, by means of two quartz photoelectric cells, incident and reflected intensities. It is shown that the minimum is very low and lies at 3160Å, in accordance with Ruben's and Hagen's measurements, only for highly polished plates. For unstrained surfaces it is shifted to lower wave lengths by about 20Å and the reflecting power rises appreciably. The shift has also been verified photographically. It is interesting to note that the effects of cold working upon the minimum are in certain respects analogous to those produced by heating.

29. Ultraviolet fluorescence of IBr and I_2. F. W. Loomis and A. J. Allen, New York University.—Using a quartz apparatus of special design, in which the fluorescence tube is completely surrounded by a water-cooled Hg arc, a fluorescence spectrum has been obtained from IBr at low pressures. It lies entirely in the ultra-violet, and is distinctly different from the spectrum of I_2 fluorescence in this region. (Oldenberg, Zeits. Phys. **18**, 1 (1923)). A series of close groups of lines is excited by λ1849, and the strongest line in each is represented by $\nu = 54{,}048 - 276.2p + 1.28p^2$, where p is an integer. At high values of p the even terms are too weak for identification, being lost in a complicated line structure, but the odd terms can be traced as strong, single lines as far as $p = 43$. Near λ2500 the line structure ceases, and a number of diffuse, headless bands extend to λ3700. This phenomenon is similar to that in I_2, where the transition to continuous bands takes place abruptly at λ2400. High dispersion photographs of the latter bands failed to reveal any line structure. The fluorescence series of I_2 excited by λ1849 and λ1942 have been photographed with resolution sufficient to show the rotational structure, permitting a correlation with the visible resonance series excited by λ5461. No fluorescence could be obtained with Br_2, ICl, or BrCl.

30. Resonance radiometry. A. H. Pfund, Johns Hopkins University.—So as to reduce the effect of spurious disturbances which limit the usefulness of usual radiometric apparatus, a system involving resonance has been constructed. A single-junction thermopile of low heat capacity is illuminated intermittently at regular intervals, and is connected to an underdamped galvanometer tuned to the period of intermittency. The deflections of this galvanometer are amplified. If a thermopile amplifier be used, the sensitivity of the best present-day radiometers is equaled. If, however, a photoelectric amplifier be employed, a thousand-fold increase is realized. By employing a tuned system throughout, great immunity from spurious disturbances is attained.

31. The effect of temperature on the absorption bands of fused quartz in the infra-red. W. A. Parlin and A. H. Pfund, Johns Hopkins University.—Specimens of fused quartz, ranging in thickness from 2.0 mm for the 3μ region, to $4 \cdot 10^{-4}$ mm for the 8μ region, were used. Measurements were taken at room temperature and at 850°C. When sufficient energy was available, an echelette grating was used for greater dispersion. In accord with previous work, the absorption band in the region of anomalous dispersion at 8.5μ was found to shift toward the red with increasing temperature. With higher resolution, fine structure bands were found which did not shift with temperature, but underwent marked changes in intensity. Several sharp bands between 2 and 4μ were found to remain fixed as the temperature was changed. A broad band at 12.5μ also remained fixed as the temperature was changed. It was found that inside of the strong bands, the absorption was less at high temperatures, while outside the band, the reverse was the case.

32. Infra-red absorption of formaldehyde vapor, I. E. O. Salant, National Research Fellow, and W. West, New York University.—Ultra-violet absorption bands of the vapor of formaldehyde, H_2CO, show rotational lines corresponding to a quite small moment of inertia of the molecule (Henri and Schou, Zeits. f. Physik., 49, 784 (1928)); consequently comparison of these bands with the infra-red rotation-vibration bands of formaldehyde offers an unique opportunity for the study of the theory of band spectra.

The measurements reported here, extending from the visible to 3.6μ, were made with a spectrometer having two sixty-degree quartz prisms, a Moll linear thermopile, thermo relay and Zernicke and Moll moving-coil galvanometers. The strongest bands, listed in the order of their intensities, were found at [3.31, 3.38, 3.47], 218, [1.77, 1.84], 191, [144, 1.40], 1.25μ. The 1.4 and 1.8μ bands appear as doublets, the 3.4μ band as a triplet with evidence of rotational structure. The separations of the lines in the 3.4μ band appear, however, markedly smaller than would be indicated by the moment of inertia derived from the ultra-violet lines. This work is being extended by means of an echelette grating spectrometer.

33. Effect of high frequency waves on the optical properties of water. A. BRAMLEY, Ph.D., Bartol Research Foundation of the Franklin Institute.—When a light of a given frequency ν is passed through a dielectric transparent to that frequency, which forms part of a parallel plate condenser, the light wave can be changed in character in two ways, when electromagnetic waves of frequency P are impressed on the condenser. First, the light train will be modulated (Abs. Dec. 1928) and secondly, the light, if it is initially plane polarized will become elliptically polarized due to the medium becoming double refracting. On measuring the amount of double refraction, i.e., the Kerr constant, for various frequencies of the oscillation applied to the Kerr cell, it was found to go through a series of maxima and minima of abnormally large amount compared to that for static electric fields. The change in frequency of the light save produced by the action of the high frequency waves also showed the same kind of periodic phenomena with change of frequency; the frequency change of the light wave varied from 0 to 0.06A°. These results indicate that the medium, water, has a set of absorption bands for high frequency radio waves which change the action of the medium for light waves passing through it.

34. Photographic spectral energy measurement with a spiral aperture disc. BRIAN O'BRIEN, Buffalo Tuberculosis Association, Perrysburg, N. Y.—A disc with a profile cut to a logarithmic spiral is rotated before the slit of a spectrograph in such a manner that, if t = integrated time of illumination of any point on the slit, $\log t = h$, where h = height above a reference point of the slit. The illumination cycle is repeated 60 times per sec. Assuming the reciprocity law and that the plate integrates intermittant exposure, then the height of the spectrum, $h' = \log I$, where I = intensity and $h' = H - h$, where H = total slit height. With the arrangement used, error in h' due to failure of reciprocity law opposes the error due to failure of plate to fully integrate the intermittent exposure, providing light intensity at the plate is less than "optimal" intensity described by Kron (Eder's Jrbch. p. 6, 1914) and investigated by Jones and collaborators (J.O.S.A. 7, p. 1079, 1923, et. seq.). The magnitude of these two errors has been investigated for variations in h' from 0 to 2.00 over a range of intensities (1 to 10,000) for five photographic emulsions of widely different speed and color sensitivity, over the range λ6000A to λ2200A. The separate errors in h' (reciprocity and intermittency failure) range from 0.04 for a fast emulsion to 0.15 for a slow emulsion for an intensity range of only 1 to 20, but the compensation of the two is complete within 0.015 in every case investigated. An intensity scale is impressed directly on the spectrum image by a comb in front of the spectrograph slit.

SUPPLEMENTARY PROGRAM

When two or more papers are offered by the same member, one only of these will be assigned a place on the regular program, while the others will be placed in a supplementary program, to be called for if time permits.

Papers received after the program has been printed will be placed in the supplementary program.

The papers in the supplementary program may be called for at any session in Room 401 after the completion of the regular program for the session.

35. Generalizations of Planck's formula. ARTHUR E. RUARK, Mellon Institute, Gulf Oil Companies and University of Pittsburgh.—In 1926, the writer studied the black body radiation laws which are obtained by assuming that the probabilities of absorption and emission are $B_\omega\rho + C_\omega\rho^2 + \cdots$ and $A + B_\omega\rho + C_\omega\rho^2 + \cdots$, respectively, instead of $B_\omega\rho$ and $A + B_\omega\rho$, used by Einstein. By studying the data of Rubens and Michel it was concluded that over their wavelength range, and up to about 3000°C, there is no convincing evidence of systematic deviations from Planck's formula of the kind required by these assumptions. Strum (Zeits. Phys. **51**, 287) has published a radiation law based on the inclusion of terms in ρ^2 in the probabilities. The writer found, however, that (on the old mechanics) the average energy of Brownian movement, $3kT/2$, is not obtained by using such a law. The interchanges of momentum between atom and radiation were calculated on the basis adopted by Einstein,—namely, quanta which merely

induce transitions pass over the atom without change in frequency or direction. The effect of modifying this assumption, and of using the new mechanics, remains to be investigated. In conclusion, stellar spectra appear to offer the most favorable opportunity for discovering deviations from Planck's law, in case they exist.

36. On hysteresis in physico-chemical systems. N. RASHEVSKY, Westinghouse Electric and Manufacturing Co.—Understanding by hysteresis the fact that the state of a system is determined not only by the instantaneous values of parameters, which characterize the external conditions, but by the previous history of the system, it is shown that whenever the equations, which determine the equilibrium of the systems, have several solutions for the same values of the parameters, the system will exhibit hysteresis. It is shown furthermore, that under certain conditions th behavior of the system will depend not only on the previous state of external conditions, but also on the rate of change of the latters.